The extended X-ray emission around HDF 130 at z=1.99: An inverse Compton ghost of a giant radio source in the Chandra Deep Field North

Reference

A.C. Fabian, S. Chapman, C.M. Casey, F. Bauer and K.M. Blundell

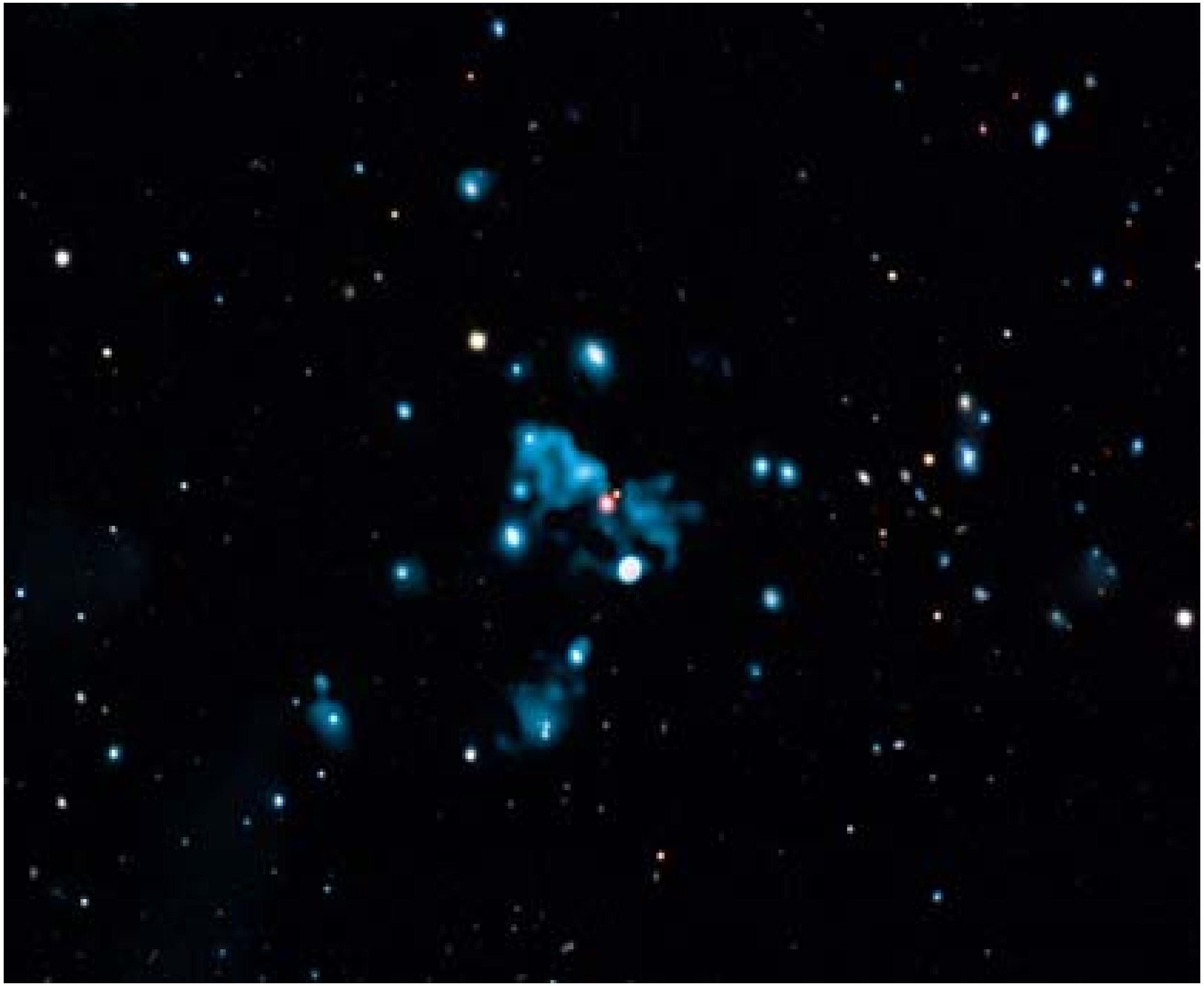
(MNRAS, 395, L67)

Wu, Ei-Han
2009/6/11

News

- This is the first detection of such a high-energy apparition.
- It is evidence of a huge eruption produced by the supermassive black hole
- A valuable opportunity to observe phenomena that occurred when the Universe was very young

HDF130: Ghost Remains After Black Hole Eruption



- Credit: X-ray (NASA/CXC/IoA/A.Fabian et al.); Optical (SDSS), Radio (STFC/JBO/MERLIN)

Fast Facts for HDF 130:

Scale: Image is 8.2 arcmin across

Coordinates (J2000) :

RA-> 12h 36m 17.6s

Dec-> +62° 15' 44.5"

Constellation: Ursa Major

Observation Date: 11/20/2000-02/22/2002

References: Fabian et al. 2009, MNRAS, 395, L67

Distance Estimate: About 10 billion light years

Release Date: May 28, 2009

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ABSTRACT
One of the six extended X-ray sources found in the Chandra Deep Field North is centred on HDF 130, which has recently been shown to be a massive galaxy at $z = 1.99$ with a compact radio nucleus. The X-ray source has a roughly double-lobed structure with each lobe about 41 arcsec long, or 345 kpc at the redshift of HDF 130. We have analyzed the 2 Ms X-ray image and spectrum of the source and find that it is well fit by a power-law continuum of photon index 2.65 and has a 2–10 keV luminosity of 5.4×10^{43} erg s^{-1} (if at $z = 1.99$). Any further extended emission within a radius of 60 arcsec has a luminosity less than half this value, which is contrary to what is expected from a cluster of galaxies. The source is best explained as an inverse Compton ghost of a giant radio source, which is no longer being powered, and for which Compton losses have downgraded the energetic electrons, $\gamma > 10^4$, required for high-frequency radio emission. The lower energy electrons, $\gamma \sim 1000$, produce X-rays by inverse Compton scattering on the Cosmic Microwave Background. Depending on the magnetic field strength, some low frequency radio emission may remain. Further inverse Compton ghosts may exist in the Chandra deep fields and beyond.

Key words: X-rays: galaxies — galaxies: clusters — intergalactic medium — galaxies:individual (RG J123617)

1 INTRODUCTION

The deepest published X-ray image dra Deep Field North (CDFN: Alex (2002) studied the 6 extended sour posure of this field and inferred th ters and groups. Casey et al (2008) h HDF 130, at the centre of one of thes CDFN J123620.0+621554, of Bauer et al 2002), is a massive elliptical galaxy at redshift $z = 1.99$, and not a starburst galaxy as earlier supposed. HST/NICMOS and Spitzer/IRAC imaging have revealed that the object has a massive ($\sim 3 \times 10^{11}$ M$_\odot$) old stellar population with a large diameter of about 8 kpc. It is intrinsically weak at submillimetre wavelengths and has a compact radio source, indicative of a central Active Galactic Nucleus (AGN). We investigate here the possibility that the double-lobed structure of the extended X-ray source is not then due to a surrounding merging cluster, as suggested by Bauer et al (2002), but instead to inverse Compton (IC) emission from a past outburst of the galaxy. The object would in the past have appeared as a giant radio galaxy, but inverse Compton (Fabian et al 2003), 6C 0905+39 ($z = 1.833$, Blundell et al 2006; Erlund et al 2008) and 4C 23.56 ($z = 2.48$; Johnson et al 2007). The flux of the emission depends on the energy density of the target photons, which in the case of the CMB rises as $(1+z)^4$ so cancelling out the dimming expected from increased distance (Felten & Rees 1969; Schwartz 2002). In the case of 3C 294 there are distinct large patches of X-ray emission separate from the observed radio source (Erlund et al 2006) and in 6C 0905+39 most of the X-ray emission lies in between the hotspots where no radio emission is seen (Erlund et al 2008). The lifetime of the electrons in the sources scales as $1/\gamma$ due to radiative losses. Lorentz factors of $\gamma \sim 1000$ are required to upscatter the CMB photons and $\gamma \sim 10^4$ (depending on the magnetic field strength) to generate GHz synchrotron radiation in the radio band. Consequently when the AGN switches off and no further electron acceleration takes place, the

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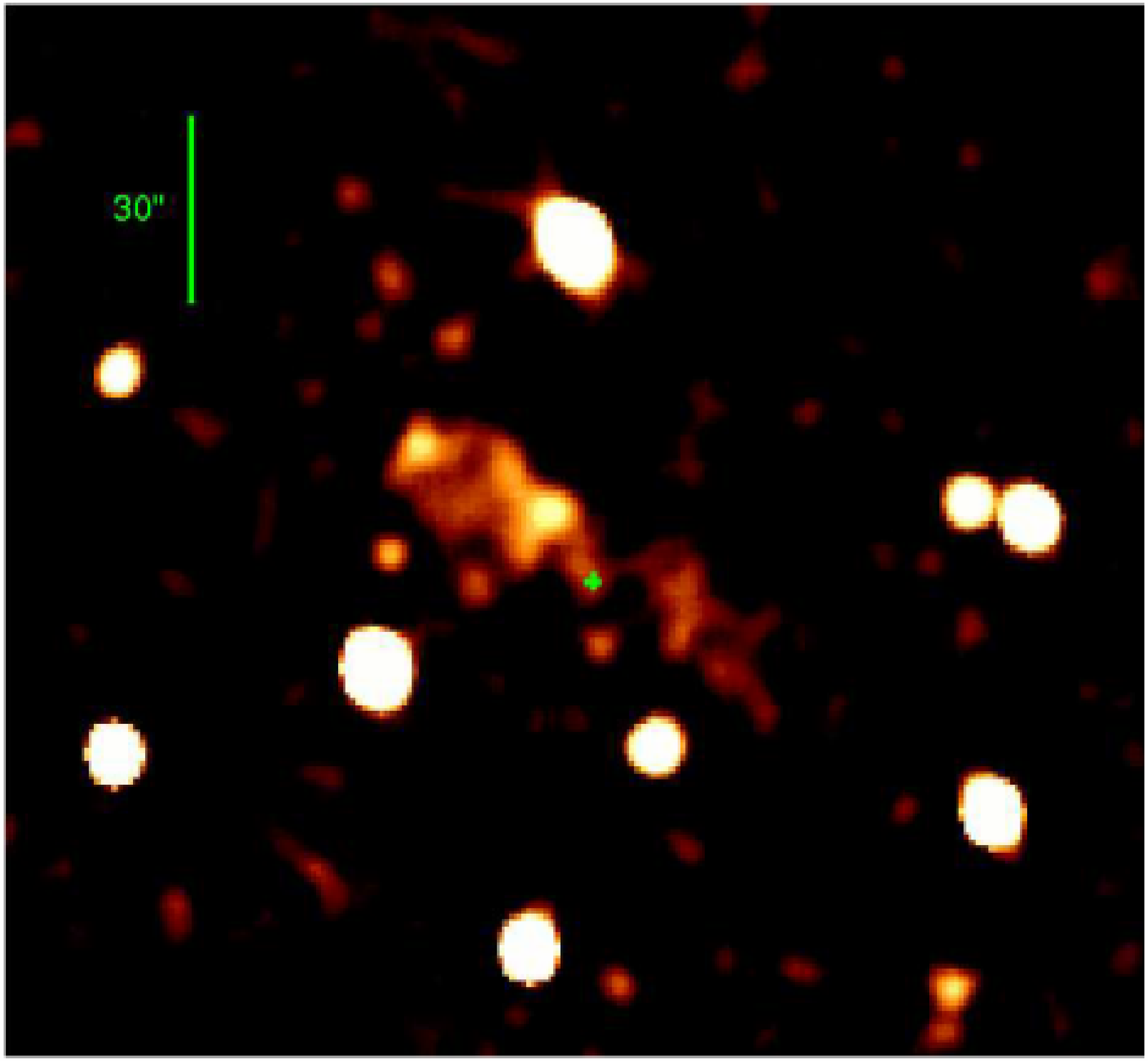

Figure 1. X-ray image of the source in the 0.3–3 keV band. The data have been binned into 1 arcsec pixels and gaussian smoothed by 5 pixels. 20 arcsec is indicated by the bar on the left and the position of the massive galaxy HDF 130 hosting the (unresolved) radio source of Casey et al (2008) is marked by a cross.

Conclusions

This could mean that the radio source is only detectable at low radio frequencies (few 100 MHz) and thus, for example, with the giant metrewave radio telescope (GMRT) or in the future with Low Frequency Array (LOFAR) and similar instruments.

Bauer et al (2002) note that there may be about 150 extended X-ray sources per square degree. If even 10 per cent of them are similar to the HDF 130 source then they have a space density of roughly 10^{-6} Mpc^{-3} (3×10^{-8} Mpc^{-3} in comoving units), close to the estimate of Celotti & Fabian (2004) for sources of luminosity $\sim 10^{44}$ erg s^{-1}. The Compton cooling time at $z = 2$ is about 30 Myr, whereas the time from $z = 2.5$ to 1.5 is about 1.7 Gyr. Therefore the space density of objects giving rise to ghosts (assuming they each only undergo one jet-active phase) is 50 times the above value or $\sim 10^{-6}$ Mpc^{-3} in comoving units, comparable to the number density of massive galaxies ($M_K < 25$; Cole et al 2001). It is even higher if expansion losses dominate, as expected.

A direct demonstration of our IC explanation for the extended X-ray emission around HDF130 would be the clear detection and mapping of the radio source itself at low radio frequencies (e.g. 100 MHz), where the Compton losses are less and the emitting electrons closer in energy to the X-ray ones.

We conclude that the X-ray Sky may be littered with faint inverse Compton ghosts.

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Thank you